XXII. *Experiments and Obſervations on Electricity. By Mr.* William Nicholſon; *communicated by Sir* Joſeph Banks, *Bart. P. R. S.*

Read June 25, 1789.

Sect. I. *On the Excitation of Electricity.*

1. A GLASS cylinder was mounted, and a cuſhion applied with a ſilk flap, proceeding from the edge of the cuſhion over its ſurface, and thence half round the cylinder. The cylinder was then excited by applying an amalgamed leather in the uſual manner. The electricity was received by a conductor, and paſſed off in ſparks to Lane's electrometer. By the frequency of theſe ſparks, or by the number of turns required to cauſe ſpontaneous exploſion of a jar, the ſtrength of the excitation was aſcertained.

2. The cuſhion was withdrawn about one inch from the cylinder, and the excitation performed by the ſilk only. A ſtream of fire was ſeen between the cuſhion and the ſilk; and much fewer ſparks paſſed between the balls of the electrometer.

3. A roll of dry ſilk was interpoſed, to prevent the ſtream from paſſing between the cuſhion and the ſilk. Very few ſparks then appeared at the electrometer.

4. A metallic rod, not inſulated, was then interpoſed, inſtead of the roll of ſilk, ſo as not to touch any part of the apparatus.

apparatus. A denſe ſtream of electricity appeared between the rod and the ſilk, and the conductor gave very many ſparks.

5. The knob of a jar being ſubſtituted in the place of the metallic rod, it became charged negatively.

6. The ſilk alone, with a piece of tin-foil applied behind it, afforded much electricity, though leſs than when the cuſhion was applied with a light preſſure. The hand, being applied to the ſilk as a cuſhion, produced a degree of excitation ſeldom equalled by any other cuſhion.

7. The edge of the hand anſwered as well as the palm.

8. When the excitation by a cuſhion was weak, a line of light appeared at the anterior part of the cuſhion, and the ſilk was ſtrongly diſpoſed to receive electricity from any uninſulated conductor. Theſe appearances did not obtain when the excitation was by any means made very ſtrong.

9. A thick ſilk, or two or more folds of ſilk, excited worſe than a ſingle very thin flap. I uſe the ſilk which the milleners call Perſian.

10. When the ſilk was ſeparated from the cylinder, ſparks paſſed between them; the ſilk was found to be in a weak negative, and the cylinder in a poſitive ſtate.

The foregoing experiments ſhew that the office of the ſilk is not merely to prevent the return of electricity from the cylinder to the cuſhion, but that it is the chief agent in the excitation; while the cuſhion ſerves only to ſupply the electricity, and perhaps increaſe the preſſure at the entering part. There likewiſe ſeems to be little reaſon to doubt but that the diſpoſition of the electricity to eſcape from the ſurface of the cylinder is not prevented by the interpoſition of the ſilk, but by a compenſation after the manner of a charge; the ſilk being then as ſtrongly negative as the cylinder is poſitive: and, laſtly, that the line of light between

between the ſilk and cuſhion in weak excitations does not conſiſt of returning electricity, but of electricity which paſſes to the cylinder, in conſequence of its not having been ſufficiently ſupplied, during its contact with the rubbing ſurface.

11. When the excitation was very ſtrong in a cylinder newly mounted, flaſhes of light were ſeen to fly acroſs its inſide, from the receiving ſurface to the ſurface in contact with the cuſhion, as indicated by the bruſh figure. Theſe made the cylinder ring as if ſtruck with a bundle of ſmall twigs. They ſeem to have ariſen from part of the electricity of the cylinder taking the form of a charge. This appearance was obſerved in a nine-inch and a twelve-inch cylinder, and the property went off in a few weeks. Whence it appears to have been chiefly occaſioned by the rarity of the internal air produced by handling, and probably reſtored by gradual leaking of the cement.

12. With a view to determine what happens in the inſide of the cylinder, recourſe was had to a plate machine. One cuſhion was applied with its ſilken flap. The plate was nine inches in diameter and two-tenths of an inch thick. During the excitation, the ſurface oppoſite the cuſhion ſtrongly attracted electricity, which it gave out when it arrived oppoſite the extremity of the flap. So that a continual ſtream of electricity paſſed through an inſulated metallic bow terminating in balls, which were oppoſed, the one to the ſurface oppoſite the extremity of the ſilk, and the other oppoſite the cuſhion; the former ball ſhewing poſitive, and the latter negative ſigns. The knobs of two jars being ſubſtituted in the place of theſe balls, the jar, applied to the ſurface oppoſed to the cuſhion, was charged negatively, and the other poſitively. This diſpoſition of the back ſurface ſeemed, by a few trials, to be weaker the

4 ſtronger

ftronger the action of the cufhion, as judged by the electricity on the cufhion fide.

Hence it follows, that the internal furface of a cylinder is o far from being difpofed to give out electricity during the friction by which the external furface acquires it, that it even greedily attracts it.

13. A plate of glafs was applied to the revolving plate, and thruft under the cufhion in fuch a manner as to fupply the place of the filk flap. It rendered the electricity ftronger, and appears to be an improvement of the plate machine; to be admitted if there were not effential objections againft the machine itfelf.

14. Two cufhions were then applied on the oppofite furfaces with their filk flaps, fo as to clafp the plate between them. The electricity was received from both by applying the finger and thumb to the oppofite furfaces of the plate. When the finger was advanced a little towards its correfpondent cufhion, fo that its diftance was lefs than between the thumb and its cufhion, the finger received ftrong electricity, and the thumb none; and, contrariwife, if the thumb were advanced beyond the finger, it received all the electricity, and none paffed to the finger. This electricity was not ftronger than was produced by the good action of one cufhion applied fingly.

15. The cufhion in experiment 12. gave moft electricity when the back furface was fupplied, provided that furface was fuffered to retain its electricity till the rubbed furface had given out its electricity.

From the two laft paragraphs it appears, that no advantage is gained by rubbing both furfaces; but that a well managed friction on one furface will accumulate as much electricity as the prefent methods of excitation feem capable of collecting; but

but that when the excitation is weak, on account of the electric matter not passing with sufficient facility to the rubbed surface, the friction enables the opposite surface to attract or receive it, and if it be supplied, both surfaces will pass off in the positive state; and either surface will give out more electricity than is really induced upon it, because the electricity of the opposite surface forms a charge. It may be necessary to observe, that I am speaking of the facts or effects produced by friction; but how the rubbing surfaces act upon each other to produce them, whether by attraction, or otherwise, I do not here enquire.

It will hereafter be seen, that plate machines do not collect more electricity than cylinders (in the hands of the electrical operators of this metropolis) do with half the rubbed surface; which is a corroboration of the inference here made.

16. When a cylinder is weakly excited, the appearances mentioned (par. 8.) are more evident, the more rapid the turning. In this case, the avidity of the surface of the cylinder beneath the silk is partly supplied from the edge of the silk which throws back a broad cascade of fire, sometimes to the distance of above twelve inches. From these causes it is that there is a determinate velocity of turning required to produce the maximum of intensity in the conductor. The stronger the excitation the quicker may be the velocity; but it rarely exceeds five feet of the glass to pass the cushion in a second.

17. If a piece of silk be applied to a cylinder, by drawing down the ends, so that it may touch half the circumference, and the cylinder be then turned and excited by applying the amalgamed leather, it will become very greedy of electricity during the time it passes under the silk. And if the entering surface of the glass be supplied with electricity, it will give it out at the other extremity of contact; that is to say, if insu-

lated conductors be applied at the touching ends of the ſilk, the one will give, and the other receive, electricity until the intenſities of their oppoſite ſtates are as high as the power of the apparatus can bring them; and theſe ſtates will be inſtantly reverſed by turning the cylinder in the oppoſite direction.

As this diſcovery promiſes to be of the greateſt uſe in electrical experiments, becauſe it affords the means of producing either the plus or minus ſtates in one and the ſame conductor, and of inſtantly repeating experiments with either power, and without any change of poſition or adjuſtment of the apparatus, it evidently deſerved the moſt minute examination.

18. There was little hope (par. 6.) that cuſhions could be diſpenſed with. They were therefore added; and it was then ſeen, that the electrified conductors were ſupplied by the difference between the action of the cuſhion which had the advantage of the ſilk and that which had not; ſo that the naked face of the cylinder was always in a ſtrong electric ſtate. Methods were uſed for taking off the preſſure of the receiving cuſhion; but the extremity of the ſilk, by the conſtruction, not being immediately under that cuſhion, gave out large flaſhes of electricity with the power that was uſed. Neither did it appear practicable to preſent a row of points or other apparatus to intercept the electricity which flew round the cylinder; becauſe ſuch an addition would have materially diminiſhed the intenſity of the conductor, which in the uſual way was ſuch as to flaſh into the air from rounded extremities of four inches diameter, and made an inch and half ball become luminous and blow like a point. But the greateſt inconvenience was, that the two ſtates with the backward and forward turn were ſeldom equal; becauſe the diſpoſition of the amal-

gam

gam on the ſilk, produced by applying the leather to the cylinder in one direction of turning, was the reverſe of what muſt take place when the contrary operation was performed.

Notwithſtanding all this, as the intenſity with the two cuſhions was ſuch as moſt operators would have called ſtrong, the method may be of uſe, and I ſtill mean to make more experiments when I get poſſeſſion of a very large machine which is now in hand.

19. The more immediate advantage of this diſcovery is, that it ſuggeſted the idea of two fixed cuſhions with a moveable ſilk flap and rubber. Upon this principle, which is ſo ſimple and obvious, that it is wonderful it ſhould have been ſo long overlooked, I have conſtructed a machine with one conductor, in which the two oppoſite and equal ſtates are produced by the ſimple proceſs of looſening the leather rubber, and letting it paſs round with the cylinder (to which it adheres) until it arrives at the oppoſite ſide, where it is again faſtened. A wiſh to avoid prolixity prevents my deſcribing the mechaniſm by which it is let go, and faſtened in an inſtant, at the ſame time that the cuſhion is made either to preſs or is withdrawn, as occaſion requires.

20. Although the foregoing ſeries of experiments naturally lead us to conſider the ſilk as the chief agent in excitation; yet as this buſineſs was originally performed by a cuſhion only, it becomes an object of enquiry to determine what happens in this caſe.

21. The great BECCARIA * inferred, that in a ſimple cuſhion, the line of fire, which is ſeen at the extremity of contact from which the ſurface of the glaſs recedes, conſiſts of returning electricity; and Dr. NOOTH grounded his happy

* Philoſophical Tranſactions, Vol. LVI. p. 117.

 invention

invention of the ſilk flap upon the ſame ſuppoſition. The former aſſerts, that the lines of light both at the entering and departing parts of the ſurface are abſolutely ſimilar; and thence infers, that the cuſhion receives on the one ſide, as it certainly does on the other. I find, however, that the fact is directly contrary to this aſſertion; and that the oppoſite inference ought to be made, as far as this indication can be reckoned concluſive: for the entering ſurface exhibits many luminous perpendiculars to the cuſhion, and the departing ſurface exhibits a neat uniform line of light. This circumſtance, together with the conſideration that the line of light behind the ſilk in par. 8. could not conſiſt of returning electricity, ſhewed the neceſſity of farther examination. I therefore applied the edge of the hand as a rubber, and by occaſionally bringing forward the palm, I varied the quantity of electricity which paſſed near the departing ſurface. When this was the greateſt, the ſparks at the electrometer were the moſt numerous. But, as the experiment was liable to the objection that the rubbing ſurface was variable, I paſted a piece of leather upon a thin flat piece of wood, then amalgamed its whole ſurface, and cut its extremity off in a neat right line cloſe to the wood. This being applied by the conſtant action of a ſpring againſt the cylinder, produced a weak excitation, and the line where the contact of the cylinder and leather ceaſed (as abruptly as poſſible) exhibited a very narrow fringe of light. Another piece of wood was prepared of the ſame width as the rubber, but one quarter of an inch thick, with its edges rounded, and its whole ſurface covered with tin-foil. This was laid on the back of the rubber, and was there held by a ſmall ſpring, in ſuch a manner as that it could be ſlided onward, ſo as occaſionally to project beyond the rubber, and cover the departing and excited ſurface

of

of the cylinder, without touching it. The ſparks at the electrometer were four times as numerous when this metallic piece was thus projected; but no electricity was obſerved to paſs between it and the cylinder. The metallic piece was then held in the hand to regulate its diſtance from the glaſs; and it was found, that the ſparks at the electrometer increaſed in number as it was brought nearer, until light appeared between the metal and the cylinder, at which time they became fewer the nearer it was brought, and at laſt ceaſed when it was in contact.

The following concluſions appear to be deducible from theſe experiments. 1. The line of light on a cylinder departing from a ſimple cuſhion conſiſts of returning electricity; 2. the projecting part of the cuſhion compenſates the electricity upon the cylinder, and by diminiſhing its intenſity prevents its ſtriking back in ſuch large quantities as it would otherwiſe do; 3. that if there were no ſuch compenſation, very little of the excited electricity would be carried off; and, 4. that the compenſation is diminiſhed, or the intenſity increaſed, in an higher ratio than that of the diſtance of the compenſating ſubſtance; becauſe if it were not, the electricity which has been carried off from an indefinitely ſmall diſtance, would never fly back from a greater diſtance and form the edge of light.

22. I hope the conſiderable intenſity I ſhall ſpeak of will be an apology for deſcribing the manner in which I produce it. I wiſh the theory of this very obſcure proceſs were better known; but no conjecture of mine is worth mentioning. The method is as follows:

Clean the cylinder, and wipe the ſilk.

Greaſe the cylinder by turning it againſt a greaſed leather till it is uniformly obſcured. I uſe the tallow of a candle.

Turn

Turn the cylinder till the ſilk flap has wiped off ſo much of the greaſe as to render it ſemi-tranſparent.

Put ſome amalgam on a piece of leather, and ſpread it well ſo that it may be uniformly bright. Apply this againſt the turning cylinder. The friction will immediately increaſe, and the leather muſt not be removed until it ceaſes to become greater.

Remove the leather, and the action of the machine will be very ſtrong.

My rubber, as before obſerved, conſiſts of the ſilk flap paſted to a leather, and the cuſhion is preſſed againſt the ſilk by a ſlender ſpiral ſpring in the middle of its back. The cuſhion is looſely retained in a groove, and reſts againſt the ſpring only, in ſuch a manner that by a ſort of libration upon it as a fulcrum, it adapts itſelf to all the irregularities of the cylinder, and never fails to touch in its whole length. There is no adjuſtment to vary the preſſure, becauſe the preſſure cannot be too ſmall when the excitation is properly made. Indeed, the actual withdrawing of the cuſhion to the diſtance of one-tenth of an inch from the ſilk, as in par. 2. will not materially affect a good excitation.

The amalgam is that of Dr. HIGGINS, compoſed of zinc and mercury. If a little mercury be added to melted zinc, it renders it eaſily pulverable, and more mercury may be added to the powder to make a very ſoft amalgam. It is apt to cryſtallize by repoſe, which ſeems in ſome meaſure to be prevented by triturating it with a ſmall proportion of greaſe: and it is always of advantage to triturate it before uſing.

A very ſtrong excitation may be produced by applying the amalgamed leather to a clean cylinder with a clean ſilk. But

it ſoon goes off, and is not ſo ſtrong as the foregoing, which laſts ſeveral days.

23. To give ſome diſtinctive criterions by which other electricians may determine whether the intenſity they produce exceeds or falls ſhort of that which this method affords, I ſhall mention a few facts.

With a cylinder 7 inches diameter and cuſhion 8 inches long, three bruſhes at a time conſtantly flew out of a three-inch ball in a ſucceſſion too quick to be counted, and a ball of 1½ inch diameter was rendered luminous, and produced a ſtrong wind like a point. A nine-inch cylinder with an eight-inch cuſhion occaſioned frequent flaſhes from the round end of a conductor 4 inches diameter: with a ball of 2½ inches diameter the flaſhes ceaſed now and then, and it began to appear luminous: a ball of 1½ inch diameter firſt gave the uſual flaſhes; then, by quicker turning, it became luminous with a bright ſpeck moving about on its ſurface, while a conſtant ſtream of air ruſhed from it; and, laſtly, when the intenſity was greateſt, bruſhes, of a different kind from the former, appeared. Theſe were leſs luminous, but better defined in the branches; many ſtarted out at once with a hoarſe ſound. They were reddiſh at the ſtem, ſooner divided, and were greeniſh at the point next the ball, which was braſs. A ball of $\frac{4}{10}$ inch diameter was ſurrounded by a ſteady faint light, enveloping its exterior hemiſphere, and ſometimes a flaſh ſtruck out at top. When the excitation was ſtrongeſt a few flaſhes ſtruck out ſideways. The horizontal diameter of the light was longeſt, and might meaſure one inch, the ſtem of the ball being vertical.

This laſt phænomenon is ſimilar to a natural event related by M. Loammi Baldwin *, who raiſed an electrical kite in

* Memoirs of the American Academy, Vol. I. p. 257.

July,

July, 1771, during the approach of a ſevere thunder-ſtorm, and obſerved himſelf to be ſurrounded by a rare medium of fire, which, as the cloud roſe nearer the zenith, and the kite roſe higher, continued to extend itſelf with ſome gentle faint flaſhes. Mr. BALDWIN felt no other effect than a general weakneſs in his joints and limbs, and a kind of liſtleſs feeling; all which he obſerves might poſſibly be the effect of ſurprize, though it was ſufficient to diſcourage him from perſiſting in any farther attempt at that time. He therefore drew in his kite, and retired to a ſhop till the ſtorm was over, and then went to his houſe, where he found his parents and friends much more ſurpriſed than he had been himſelf; who, after expreſſing their aſtoniſhment, informed him, that he appeared to them (during the time he was raiſing the kite) to be in the midſt of a large bright flame of fire, attended with flaſhings; and that they expected every moment to ſee him fall a ſacrifice to the flame. The ſame was obſerved by ſome of his neighbours, who lived near the place where he ſtood.

This fact is ſimilar to another obſerved by M. DE SAUSSURE on the Alps, and both are referable to my luminous ball with the ſecond kind of bruſh. The cloud muſt have been negative.

With a 12-inch cylinder, and rubber of 7½ inches, a five-inch ball gave frequent flaſhes, upwards of 14 inches long, and ſometimes a ſix-inch ball would flaſh. I do not mention the long ſpark, becauſe I was not provided with a favourable apparatus for the two larger cylinders. The 7-inch cylinder affords a ſpark of 10¾ inches at beſt. The 9-inch cylinder, not having its conductor inſulated on a ſupport ſufficiently high, afforded flaſhes to the table which was 14 inches diſtant. And the 12-inch cylinder, being mounted only as a model or trial for conſtructing a larger apparatus, is defective in ſeveral

reſpects

respects which I have not thought fit to alter. When the five-inch ball gives flashes, the cylinder is enveloped on all sides with fire which rushes from the receiving part of the conductor. I never use points, but in a simple machine bring the conductor almost in contact with the cylinder. In this apparatus that cushion to which the rubber is not applied serves that purpose.

24. These marks exhibit the intensity as deduced from simple electrifying. I will now mention the rate of charging, which was nearly the same in all the three cylinders.

A large jar of 350 square inches, or near $2\frac{1}{2}$ square feet, with an uncoated varnished rim, of more than four inches in height, was made to explode spontaneously over the rim. The jar, when broken, proved to be 0.082 inches thick on an average; and the number of square feet of the surface of the cylinder which was rubbed, to produce the charge of one foot, was, when least, 18.03, and when most, with good excitation, 19.34. The great machine at Harlem charges * a single jar of one foot square by the friction of 66.6 square feet, and charges its battery of 225 square feet at the rate of 94.8 square feet rubbed for each foot. The intensity of electricity on the surface of the glass is therefore considerably less than one-fourth of that here spoken of; but if we take the most favourable number 66.6 at the commencement of turning, and halve it on account of the unavoidable imperfection of a plate machine (as shewn in par. 14.), it will be found, that the management applied to that machine would cause a cylinder to charge one square foot by the friction of $33\frac{1}{3}$ square feet. It must be observed, however, that M. VAN MARUM's own machine, con-

* To explode from the central wire, which, from some trials, I find to require less force than from coating to coating at equal distances.

fifting of two plates, 33 inches diameter, has only half the intenfity, though he reckons it a very good one. This machine is about equal in abfolute power to my 9-inch cylinder, with its fhort rubber; but it is near thirty times as dear in price. In all thefe deductions I omit the computations, for the fake of brevity, and becaufe they are eafily made. The *data* are found in the defcription of the Teylerian machine, and its continuation publifhed at Harlem in the years 1785 and 1787.

I fhall here take the liberty of obferving, that the action of the cylinder, by a fimple cufhion or the hand, which excited the aftonifhment of all Europe, in the memory of our co-temporaries, was firft improved by the addition of a leathern flap; then by moiftening the rubber; afterwards by applying the amalgam; and, laftly, by the addition of a filk flap. Now, I find, by experiment, that we at prefent obtain upwards of forty times the intenfity which the bare hand produces; and confequently that, fince eighteen times our prefent intenfity will equal the utmoft we can now condenfe on ftrong glafs even in the form of a charge; we have a lefs ftep to take before we arrive at that amazing power, than our immediate predeceffors have already made.

My 9-inch cylinder, when broken, proved to be $\frac{1}{21}$ of an inch thick.

SECT. II. *Upon the luminous Appearances of Electricity and the Action of Points.*

25. Some of the luminous appearances, with balls in the pofitive ftate, have been flightly noticed as criterions of intenfity. I fhall here add, that the efcape of negative electricity from a ball is attended with the appearance of ftrait fharp fparks with a

hoarse or chirping noise. When the ball was less than two inches in diameter, it was usually covered with short flames of this kind, which were very numerous.

26. When two equal balls were presented to each other, and one of them was rendered strongly positive, while the other remained in connection with the earth, the positive brush or ramified spark was seen to pass from the electrified ball: when the other ball was electrified negatively, and the ball, which before had been positive, was connected with the ground, the electricity (passing the same way according to FRANKLIN) exhibited the negative flame, or dense straight and more luminous spark, from the negative ball; and when the one ball was electrified *plus* and the other *minus*, the signs of both electricities appeared. If the interval was not too great, the long zig-zag spark of the *plus* ball struck to the strait flame of the *minus* ball, usually at the distance of about one-third of the length of the latter from its point, rendering the other two-thirds very bright. Sometimes, however, the positive spark struck the ball at a distance from the negative flame. These effects are represented in Plate IV. fig. 1, 2 and 3.

27. Two conductors of three-quarters of an inch diameter, with spherical ends of the same diameter, were laid parallel to each other, at the distance of about two inches, in such a manner as that the ends pointed in opposite directions, and were six or eight inches asunder. These, which may be distinguished by the letters P and M, were successively electrified as the balls were in the last paragraph. When one conductor P was positive, fig. 5. it exhibited the spark of that electricity at its extremity, and struck the side of the other conductor M. When the last-mentioned conductor M was electrified negatively, fig. 4. the former being in its turn connected with the earth,

the ſparks ceaſed to ſtrike as before, and the extremity of the electrified conductor M exhibited negative ſigns, and ſtruck the ſide of the other conductor. And when one conductor was electrified *plus* and the other *minus*, fig. 6. both ſigns appeared at the ſame time, and continual ſtreams of electricity paſſed between the extremities of each conductor to the ſide of the other conductor oppoſed to it. In each of theſe three caſes, the current of electricity, on the hypotheſis of a ſingle fluid, paſſed the ſame way.

28. In drawing the long ſpark from a ball of four inches diameter, I found it of ſome conſequence that the ſtem ſhould not be too ſhort, becauſe the vicinity of the large prime conductor altered the diſpoſition of the electricity to eſcape; I therefore made a ſet of experiments, the reſult of which ſhewed, that the diſpoſition of balls to receive or emit electricity is greateſt when they ſtand remote from other ſurfaces in the ſame ſtate; and that between this greateſt diſpoſition in any ball, whatever may be its diameter, every poſſible leſs degree may be obtained by withdrawing the ball towards the broader or leſs convex ſurface out of which its ſtem projects, until at length the ball, being wholly depreſſed beneath that ſurface, loſes the diſpoſition entirely. From theſe experiments it follows, that a variety of balls is unneceſſary in electricity; becauſe any ſmall ball, if near the prime conductor, will be equivalent to a larger ball whoſe ſtem is longer.

29. From comparing ſome experiments, made by myſelf many years ago, with the preſent ſet, I conſidered a point as a ball of an indefinitely ſmall diameter, and conſtructed an inſtrument conſiſting of a braſs ball of ſix inches diameter, through the axis of which a ſtem, carrying a fine point, was ſcrewed. When this ſtem is fixed in the prime conductor, if

the

the ball be moved on its axis in either direction, it cauſes the fine point either to protrude through a ſmall hole in its external ſurface, or to withdraw itſelf; becauſe by this means the ball runs along the ſtem. The diſpoſition of the point to tranſmit electricity may thus be made equal to that of any ball whatever, from the minuteſt ſize to the diameter of ſix inches. See fig. 7. let. A.

30. The action of pointed bodies has been a ſubject of diſcuſſion ever ſince it was firſt diſcovered, and is not yet well explained. To thoſe who aſcribe this effect to the figure of electric atmoſpheres, and their diſpoſition to fly off, it may be anſwered, that they ought firſt to prove their exiſtence, and then ſhew why the cauſe which accumulated them does not prevent their eſcape; not to mention the difficulty of explaining the nature of negative atmoſpheres. If theſe be ſuppoſed to conſiſt of electrified air, it will not be eaſy to ſhew why a current of air paſſing near a prime conductor does not deſtroy its effects. The opinion, ſupported by the celebrated VOLTA and others, that a point is the coating to an infinitely ſmall plate of air, does not appear better founded: for ſuch a plate muſt be broken through at a greater diſtance only becauſe higher charged; whence it would follow, that points ſhould not act but at high intenſities. I muſt likewiſe take notice, as a proof that the charge has little to do here, that if a ball be preſented to the prime conductor, at the ſame time that a point proceeds from the oppoſite ſide of the ball, the electricity will paſs by the point, though it is obliged to go round the ball for that purpoſe; but it can hardly be doubted, that whatever charge obtains in this caſe is on the ſurface of the ball next the conductor, and not on the remote ſide to which the electricity directs its courſe.

31. ACHARD'S

31. ACHARD'S experiments with a number of pointed cones, ſcrewed in a plate of metal, and likewiſe the pointed apparatus deſcribed (par. 29) ſhew that the effect of points depends on the remoteneſs of their extremities from the other parts of the conductor. This leads to the following general law.

In any electrified conductor the tranſition or eſcape of electricity will be made chiefly from that part of the ſurface which is the moſt remote from the natural ſtate.

Thus in the apparatus of the ball and ſtem, the point having a communication with the reſt of the whole conductor, conſtantly poſſeſſes the ſame intenſity; but the influence of the ſurrounding ſurface of the ball diminiſhes its capacity. This diminution is leſs the farther the ball is withdrawn, and conſequently the point will really poſſeſs more electricity, and be more diſpoſed to give it out when it is prominent than when depreſſed. The ſame explanation ſerves for negative electricity.

32. The effect of a poſitive ſurface appears to extend farther than that of a negative: for the point acts like a ball when conſiderably more prominent if it be poſitive than it will if negative. This property was uſed by me ſome years ago for the conſtruction of an inſtrument to diſtinguiſh the two electricities *.

For the ſake of conciſeneſs I paſs over many facts which have preſented themſelves in the courſe of my experiments on the two electricities, and content myſelf with obſerving, that there is ſcarcely any experiment made with the poſitive power which will not afford a reſult worthy of notice, if repeated with the negative.

* Introduction to Natural Philoſophy, Vol. II. p. 320.

33. When

33. When we consider that our machines can cause a ball of an inch and half diameter to act like a point, and that our apparatus makes a point act like a ball; if at the same time we remark the small elevation of our conductors for lightning above the extended surface of the ground, and the small size of the balls proposed by some to be used as terminations; the dispute, which was so much agitated respecting them, will perhaps be found to relate to a very minute circumstance, among the many which govern the great operations of nature. It does not seem probable, that any conductor would act silently if the main course of the electricity of a negative cloud were to pass through it, and many would probably receive the stroke from a positive cloud. It does not, however, follow from this, that they might not conduct it with safety.

SECT. III. *Of compensated Electricity.*

34. It is unnecessary to insist upon what is called the equilibrium of an electrical charge, because Dr. FRANKLIN has admirably explained it according to his hypothesis. But there is another important particular, which has been almost entirely overlooked, namely, the uncompensated electricity which is as essential to the charge as that which is in equilibrio. Whenever a jar is charged, the greatest part of the electricity becomes latent on account of the compensation; but there is a certain proportion which remains on the insulated side, and exerts its force to prevent the electricity from returning to the outer surface. In moderate intensities, this will explode, and carry the charge with it, to distances which are in proportion to the quantity of the charge itself; but in greater intensities the distances greatly exceed that proportion. With glasses of different thicknesses, this intensity,

as meaſured by the exploſive ſpark, is as the thickneſs, when the charges are equal, as Mr. CAVENDISH has determined, and I find likewiſe by experiments with thin ſubſtances; but when the thickneſſes are greater, it increaſes in a higher proportion, as is found by the exploſion which takes place between the electrophore and its plate, as well as by other experiments.

35. This uncompenſated part of the charge (which is commonly in proportion to the quantity of latent or compenſated electricity, or to the diſtance at which it exerts its action) was found to be greatly increaſed when a ſeries of jars were made to charge each other. If a jar be inſulated and made to explode by LANE's electrometer at a determinate number of turns; and another jar be then connected with its external coating ſo as to become charged by that means, the exploſion, from the outſide of the laſt to the inſide of the firſt, will take place at the electrometer (unaltered) with much fewer turns. Or if the electrometer be altered till the exploſion takes place at the original number, the diſtance will be much greater than before. Hence we ſee, that the intenſity of the uncompenſated part muſt be greater when there is a greater charge to be maintained, whether it be on one ſurface only, or on two ſurfaces ſucceſſively connected. I have not yet made the experiments neceſſary to aſcertain the law of this laſt action.

36. It is evident, that the breaking of jars is not effected by any attraction between the electricities which form the charge, but by this neceſſary ſurplus: for thicker glaſſes require much leſs electricity to produce an intenſity which breaks them than thinner do; and I found a piece of Muſcovy talc, one hundredth of an inch thick, to bear a charge conſiſting of ten times the quantity of electricity which was ſufficient to have charged an equal ſurface of common glaſs ſo as to break it.

But

But the intensity of the very dense charge on the talc was so low as to afford an explosion of no more than about one-tenth of an inch, while that of the glass jar it was compared with exploded through about five inches.

The perforation of glass by the long spark, or by the spark through oil or cement, seems to depend on the very great intensity of the electricity which has not time to diffuse itself, but charges a minute part of the surface very high.

37. Muscovy talc * being a very perfect non-conductor, and capable of being divided into plates of less thickness than one two-hundredth part of an inch, I made many experiments with it, which are too numerous to enter into this Paper. In consequence of its great capacity it gives very strong shocks. Contrary to the assertion of BECCARIA, I found that its laminæ are naturally in strong opposite states of electricity, and flash to each other when torn asunder in the dark. A large piece being split in two, the parts were found to be in opposite states. The greatest care was taken in these experiments to avoid friction, and to use such pieces as had never been excited, nor brought near the machine.

38. The most plausible objection against the probability of danger from the returning stroke of the Earl of STANHOPE is, that the quantity of electricity in an animal is too small to produce any mischievous effect. This the noble author has answered by remarking, that the quantity has not been shewn to be small †. My experiments with talc shewing that it naturally possesses much electricity, led me to investigate the quantity which a man may contain. I melted sealing wax upon BENNET's electrometer with a burning glass, and found it pro-

* I am not certain whether HENLEY or BECCARIA first used this substance; but little attention was paid to it by either. † Phil. Trans. Vol. LXXVII. p. 143.

duced no electricity either in heating or cooling. I alſo placed a piece of red-hot glaſs upon the ſame inſtrument, and it cooled without affording electric ſigns. Theſe experiments ſhewed, that the natural quantity of electricity is the ſame in theſe bodies, whether they be in the conducting or non-conducting ſtate; and conſequently, if it can be proved, that an electric contains a large quantity of electricity, the inference may be fairly extended to non-electrics. And it will not be diſputed, upon any hypotheſis, but that a non-conductor, or its coating, contains as much of what we call electricity as can be driven out of it in the act of charging. Two ſquare inches of talc, of the thickneſs of 0,011 inch, were repeatedly charged and made to explode over the uncoated part, by each turn of a ſeven-inch cylinder. The intenſity of the excitation was ſuch, that a conductor, of three feet long, and ſeven inches diameter, gave a denſe ſpark of 9 inches long at each turn. Now, in round numbers 45 ſuch plates of talc, laid upon each other, would have formed a ſolid inch of matter; and from this, if fitted up as a BECCARIA's battery, we could with our machine drive out electricity enough ſimply to charge a conductor 45 times as long (neglecting the ends); that is to ſay, we find that one ſolid inch of talc contains electricity enough to charge a conductor of 7 inches diameter, and 135 feet long, ſo high as to give a nine-inch ſpark at leaſt, but how much more it contains we know not.

If it be here objected, that the talc does nothing more than ſeparate the coatings, we may make uſe of gold leaf for our coating; which ſubſtance being (as I find by weight and meaſurement) no more than $\frac{1}{282000}$ of an inch thick, would increaſe the reſult near three thouſand times.

Without

Without referring to the intenfe electricity of a cloud, or the bulk of a man, it may be obferved, that fuch a fpark would be very painful. But to purfue our computation. The cylinder charged a fquare foot of glafs, of about 0.08 thick, in 15 turns fo as to explode over a rim above four inches high. Fifteen of the pieces of talc would therefore poffefs as much electricity as makes the charge of a jar of one foot fquare, and the 45 pieces or folid inch would contain enough to charge three fquare feet. If we fuppofe the bulk of a man to be only 3 folid feet or 5184 folid inches, the natural electricity of this mafs, as deduced from the foregoing facts, will be equal to the charge of a battery of upwards of 15,000 fquare feet.

I beg leave to obferve, in concluding this Paper, that I have been very careful in repeating the experiments with many precautions which the experienced in this branch of natural philofophy will perceive the neceffity of; though, in order to keep this communication within proper limits, I have here avoided a minute defcription of them. With the fame view I have likewife forborn to fpeak either of theory, or of a number of other experimental refearches I have made during the courfe of this enquiry. Dates are entirely omitted from a conviction that the priority of accidental difcovery is not worth contending for, and that no difputes ever arife about that general tenor of conduct in the cultivation of fcience, upon which the rational part of mankind ground their approbation or cenfure.

New North-ftreet,
May 14, 1789.

 P. S.

P. S. Since the above was written, the *Journal de Physique* for April, 1789, has arrived. It contains an excellent Paper of M. VAN MARUM, giving an account of ſome very conſiderable amendments of the rubber, and of the manner of applying it to plate machines. The chief improvement conſiſts in fixing the ſilk to the poſterior part of the rubber, ſo that it covers the whole face, and has the amalgam applied upon it. I cannot, however, avoid expreſſing my ſurprize, that this improvement, which has been in common uſe in England for upwards of twelve years paſt, ſhould now be offered as a diſcovery by ſo experienced a philoſopher. With his new rubbers M. VAN MARUM excites his plates of 33 inches diameter ſo ſtrongly as to produce nearly two-thirds of the former effect of the Teylerian machine, though the rubbed ſurfaces of theſe machines are now as 691 to 2409. This power would charge the ſingle jar by the friction of 28.6 ſquare feet, or the battery by rubbing 36.2 feet, inſtead of the numbers 66.6 and 94.8, as given in par. 24. This is a vaſt acquiſition of intenſity; but ſtill little more than half that of the ſurface of a cylinder, as mentioned in the ſame paragraph. But if par. 14. be admitted to prove that plate machines gain nothing by the friction of the back ſurfaces, it will follow, that M. VAN MARUM's management, if applied to a cylinder, would do better than mine.

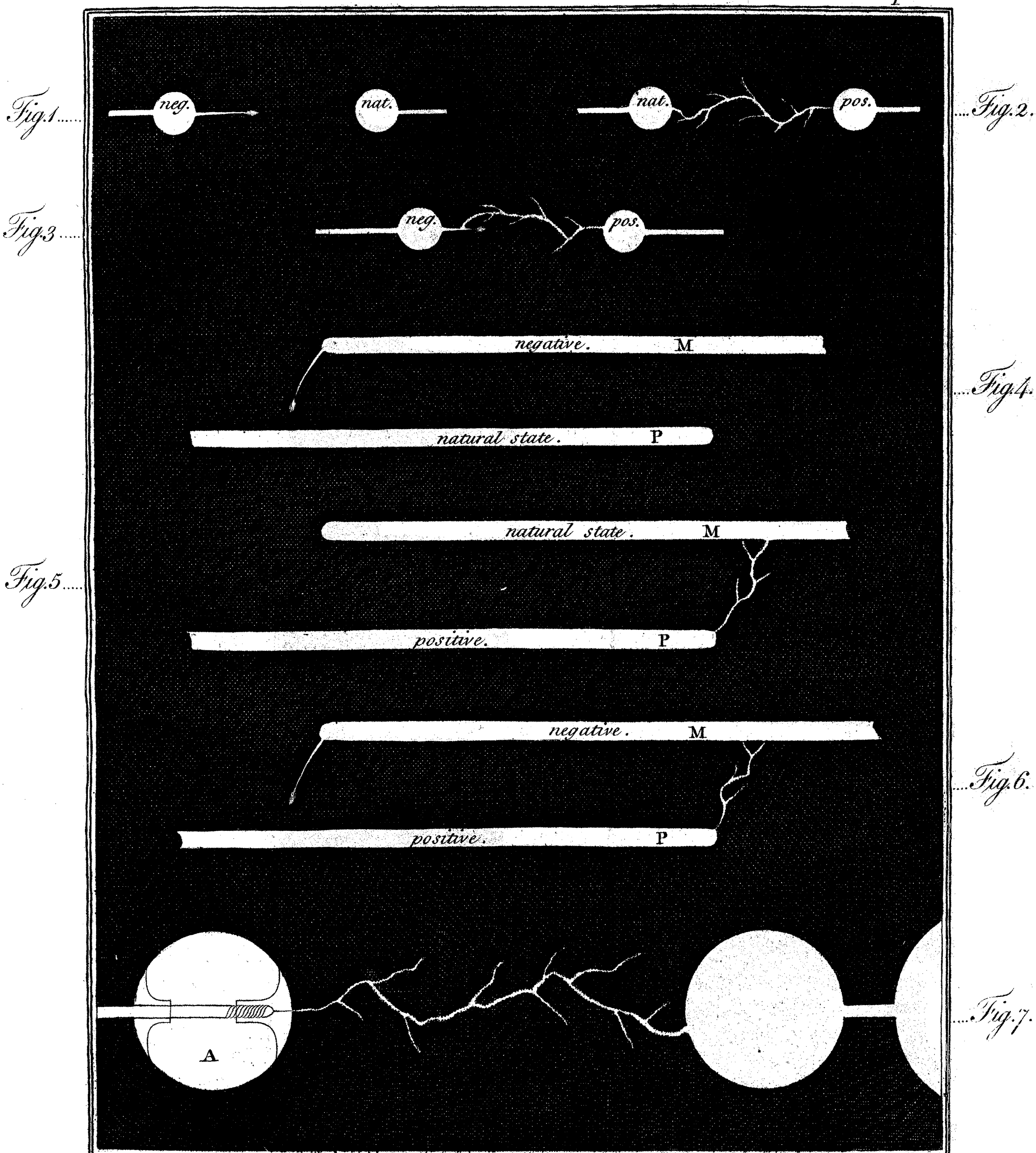
Fig. 1
neg.
nat.
Fig. 2.
nat.
pos.
Fig. 3
neg.
pos.
negative.
M
Fig. 4.
natural state.
P
natural state.
M
Fig. 5
positive.
P
negative.
M
Fig. 6.
positive.
P
A
Fig. 7.

Basire Sc.